CHAPTER 3: TECHNICAL CONSIDERATIONS

3.1 INTRODUCTION

This chapter of the Adoption Guidelines focuses on technical considerations for biofiltration systems. ***The purpose of this chapter is to supplement rather than replace existing design guidelines for biofiltration systems, as these often contain specific local requirements.*** It begins with a brief discussion of considerations in the conceptual design stage, including guidance for linking management objectives to design, a key step in biofilter design that is often overlooked. The main components of biofiltration systems and five fundamental design configurations are presented in Section 3.4. This is followed by a discussion of the design considerations for each component as well as the overall configuration (Section 3.5). Finally, specific site and application considerations are discussed (Section 3.6).

3.2 CONCEPTUAL DESIGN

It is very unlikely that any two biofilters will be exactly the same, therefore "big-picture" thinking and decisions are required before the detailed design can be specified. There are a number of existing useful conceptual design guidance documents and we refer the reader to these documents, in particular, the South East Queensland Healthy Waterways Partnership's Concept Design Guidelines for Water Sensitive Urban Design (Water by Design, 2009a). Possible considerations at the conceptual design stage could include:

- How will the biofiltration system be integrated within the urban design?
  - Scale of approach: end-of-pipe (regional, precinct) versus distributed (at-source, streetscape)
  - Drainage function: biofiltration swales are "on-line" systems and provide both treatment and conveyance, whereas biofiltration basins are "off-line" and provide treatment only. However, basins are less likely to scour because they are non-conveyance and so generally do not have to withstand high flow velocities.
- What opportunities and constraints are associated with the site?
  - Is there a landscape/urban design theme?
  - What, if any, are the treatment targets? For example, the State of Victoria requires 80, 45 and 45% load reductions of TSS, TP and TN, respectively, for new developments, while other states, such as Queensland, have treatment goals.
  - What are the local water demands?
  - What are the catchment properties? eg. size, flow rates, land use.
  - Are there any obvious sources of high pollutant loads? eg. high numbers of deciduous trees.
  - Is the site sloped? Flat? Both very sloped and very flat slopes can be challenging.
  - Is there an existing drainage system?
  - Are there existing stormwater treatment systems in the catchment? What condition are they in?
  - What services are 'in the way' of the proposed construction area?
  - What is the space availability?
  - What are the *in situ* soil properties? eg. salinity, acidity, infiltration capacity
  - How is the urban design arranged? eg. solar orientation

CONCEPTUAL DESIGN TIP

- Variations in site conditions provide the opportunity for creative design. It is important to note that what might initially be perceived as a constraint can lead to innovative solutions. These broad conceptual design ideas can then start to be developed into more detailed functional design.

IMPORTANT!

- Like all other WSUD elements, incorporation of biofilters into the urban design is far more straightforward and successful if it is considered in the initial stages of development (i.e., when the "slate is clean"), rather than after the design other elements of the urban environment (eg. roads, lot configurations) has been completed.
- It is important to design in consultation with those who will be responsible for maintaining the system to ensure practicality.

3.2.1 Linking management objectives to design

The design of a biofilter should be governed by the objectives for the particular catchment or site. Whilst this seems like an all-too-obvious statement, there is often very little thought given to the management objectives. As a result, systems are often designed in a way that is sub-optimal for the particular requirements of the site, even if it performs well for other (perhaps less important) objectives.

For example, possible objectives could include:

1. Water quality treatment (i.e., reduction in concentrations and/or loads of certain pollutants);
2. Flow management (i.e., reduction of runoff frequency and volumes or flow rates, etc.); and/or
3. Provision of pre-treated water for stormwater harvesting applications.

The optimal design of a biofilter will be very different, depending on which objective(s) are to be met. Table 2 outlines (i) design processes and the (ii) likely design attributes for each of these objectives.

There may be other objectives that also need to be considered, such as biodiversity and public amenity. These should be identified, along with site opportunities and constraints, in an initial site inspection, with ***all stakeholders*** in attendance.

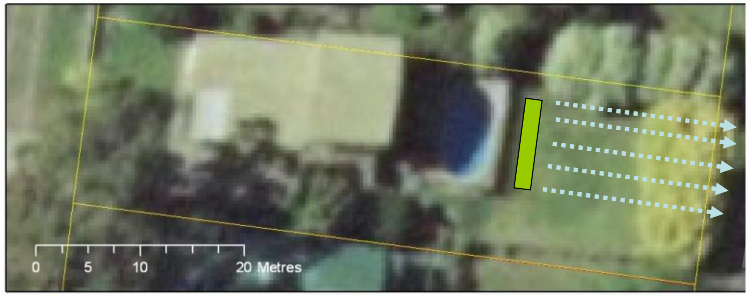
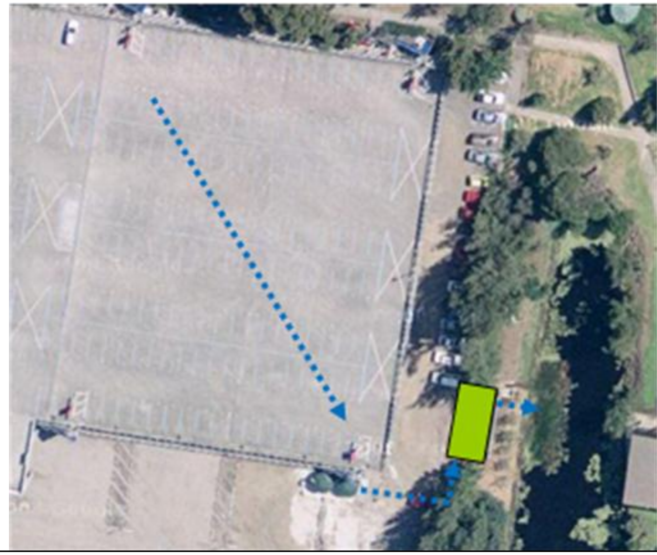
Table 2. Design procedures and design attributes of a biofilter, relative to design objectives.

Objective	Typical design procedure	Key attributes of biofilter
Water quality		
Concentrations	1. (Optionally) start with simple lookup charts for basic dimensions. 2. Model in MUSIC or similar; use Statistics or Cumulative Frequency Graphs to examine results in MUSIC. 3. Finalise design details.	1. Filter depth (enough to achieve optimal treatment) and filter type (low P index, appropriate organic matter, hydraulic conductivity, etc.) (Section 3.5.3). 2. May be lined or unlined, subject to constraints of nearby infrastructure (Section 3.5.11). 3. Submerged zone best for N removal (no significant effects for TSS, TP, metals) (Section 3.5.4). 4. Must be vegetated with optimal species for N removal (Section 3.5.12). 5. Adequate detention volume and filter area to reduce frequency of overflow (of untreated water) (Section 3.5.2).
Loads	1. (Optionally) start with simple lookup charts for basic dimensions. 2. Model in MUSIC or similar; use *Mean Annual Loads* or *Treatment Train Effectiveness*: use Mean Annual Loads or Treatment Train Effectiveness to examine results in MUSIC. 3. Finalise design details.	1. Filter depth (enough to achieve optimal treatment) and filter type (low P index, appropriate organic matter, hydraulic conductivity, etc.) (Section 3.5.3). 2. Should be unlined wherever possible, to maximise exfiltration, subject to constraints of nearby infrastructure (Section 3.5.11). 3. Must be vegetated with optimal species for N removal. (Section 3.5.4) Maximise vegetation density to maximise evapotranspiration losses. 4. Adequate detention volume and filter area to reduce frequency of overflow (of untreated water) (Section 3.5.2). Maximise filter area to maximise exfiltration.
Hydrology		
Runoff frequency reduction	1. Runoff frequency can be modelled in MUSIC (with post-analysis of the model results done in a simple spreadsheet): see Appendix B. Model is run at 6 minute timestep with results exported to Excel at daily timestep. 2. Finalise design details.	1. Must be unlined wherever possible, to maximise exfiltration, subject to constraints of nearby infrastructure (Section 3.5.11). Lining can be on one side only if necessary. 2. Must be densely vegetated to maximise evapotranspiration losses. 3. Maximise filter area to maximise exfiltration. Adequate detention volume and filter area to reduce frequency of overflow (of untreated water) (Section 3.5.2). 4. Maximise storage volume in filter; for example, consider having a deep base layer of high-porosity material (eg. scoria) to act as a 'buffer-store', particularly in the case of underlying soils with low hydraulic conductivity.

Table 2 cont...

Objective	Typical design procedure	Key attributes of biofilter
Hydrology cont...		
Peak flow reduction	1. Model in MUSIC; use <u>Statistics</u> <u>or Cumulative Frequency Graph</u> for flow to assess results (may choose to use Flow Threshold to remove zero or low flow periods). 2. Finalise design details.	1. Maximise <u>detention volume</u> and filter area to reduce rate of overflow (Section 3.5.2). 2. Maximise <u>storage volume</u> in filter; for example, consider having a deep base layer of high-porosity material (eg. scoria) to act as a 'buffer-store', particularly in the case of underlying soils with low hydraulic conductivity. 3. Preferably <u>unlined</u> wherever possible, to maximise exfiltration, subject to constraints of nearby infrastructure (Section 3.5.11). Lining can be on one side only if necessary.
Stormwater harvesting	1. Modelling may be undertaken in MUSIC, as for water quality (concentrations or loads), but also using <u>Mean Annual Loads</u> or <u>Treatment Train Effectiveness</u> to determine what proportion of inflow is passed to the stormwater harvesting store. To determine the proportion which is treated and untreated a flux file can be used in MUSIC. 2. Finalise design details.	1. System must be <u>lined</u> to minimise exfiltration losses (thus maximising harvested yield). 2. <u>Vegetation density should be reduced</u> in order to reduce evapotranspiration losses. Shallow-rooted plants will result in less losses (but this will need to be traded off against the reduced nitrogen treatment; the optimal solution will depend on the end-use of the water and when nitrogen removal is important). 3. The proportion of water treated should be maximised (to maximise harvested yield) by <u>maximising detention volume and filter area</u>. Where the end-use is sensitive to changes in water quality, overflows from the biofilter should not be allowed to enter the harvesting store.

3.2.2 Case Study

	Little Stringybark Creek biofiltration project		Monash stormwater harvesting system
Context:	Project undertaken as part of a large-scale catchment retrofit project to restore Little Stringybark Creek by reducing the impacts from stormwater runoff. A study of this catchment had showed that the frequency of urban runoff was a key driver of degradation.	Context:	Project undertaken by FAWB and Monash University's Water Conservation Committee to capture and treat stormwater runoff from a multi-level carpark on the Clayton campus of Monash University. The treated water would then be used irrigate an adjacent sports ground.
Objectives:	1. Reduce runoff frequency to pre-development level of 15 days per year. 2. Reduce annual loads of TSS, TP and TN loads by 80, 45 and 45% respectively. 3. Maximise biodiversity benefits.	Objectives:	1. Maximise volume of treated water available for irrigation. 2. Reduce annual loads of TSS, TP and TN loads by 80, 45 and 45% respectively.
Catchment:	System is to be built to treat a house (265m^2) and surrounding paved area (200m^2). Hence catchment area = 465 m^2.	Catchment:	System is to be built to treat a paved carpark (4500 m^2).
			
Opportunities:	1. There is a large area available (although the property owners would prefer to minimise the amount of space lost). 2. A large lawn area below the proposed biofilter location could be used for infiltration of overflows, before it reaches the street drainage.	Opportunities:	1. There is an existing ornamental pond that can act as a store for the treated water.

	Little Stringybark Creek biofiltration project		Monash stormwater harvesting system
Constraints:	1. The underlying soils in the area have a hydraulic conductivity of around 0.1mm/hr 2. Being a private property, safety considerations must be foremost and so the extended detention depth must be kept shallow. 3. Nearby infrastructure (a swimming pool) required lining of the system on the closest side.	Constraints:	1. Available space for the biofiltration system is limited as existing tress cannot be removed. 2. Half of the carpark drains to the south; this drainage system cannot be accessed due to the slope of the site (i.e., this system is lower than the biofilter inlet).
Design process:	MUSIC was used to model the runoff frequency. A 6-minute timestep was used, and the results exported to Excel at a daily timestep. The number of days runoff was thus counted, using the Excel function "=countif(A1:A365,"0")". Designs were trialled until the target of 15 days runoff per year was achieved.	Design process:	MUSIC was used to model the pollutant removal efficiency and treated volume using a 6-minute timestep. The reduction in loads discharged to the drainage system was assessed using the Treatment Train Effectiveness at the pond, the reduction in pollutant concentrations in the irrigation water was assessed using Statistics, and the volume available for use was assessed using Mean Annual Loads.
Chosen elements:	Meeting the runoff frequency objective was much more difficult than meeting the pollutant load reduction target. Thus the design was driven by the need to reduce runoff frequency. The resulting system had the following elements: 1. An area of 11m^2, with a ponding depth of 20cm and filter depth of 80 cm. 2. The bottom 35cm of the filter was made up of scoria, to maximise the available storage in the filter. The remaining filter was made up of a loamy sand (with two transition layers – a fine gravel and a medium sand – in between the loamy sand and the scoria layer. 3. The system was <u>unlined</u>, except for the side closest to the swimming pool. 4. No underdrain was used – the system operates entirely by infiltration, since runoff frequency needed to be minimised. 5. The system was densely planted with indigenous plants to (a) maximise evapotranspiration and (b) meet biodiversity objectives.	Chosen design solution:	The system is small relative to its catchment area and therefore overflow occurs frequently. This is not particularly problematic for harvesting (because the water is always pre-treated in two sedimentation tanks, where heavy metal concentrations are reduced, and high nutrient levels are not detrimental for this irrigation application) and, since overflows discharge to the storage pond, load reductions will still be achieved, provided overflow from the pond to the conventional stormwater drainage system is minimised. This can be achieved by keeping the pond slight drawn down. The resulting system had the following elements: 1. A surface area of 45 m^2, with a ponding depth of 25 cm and filter depth of 70 cm. 2. The filter was made up of 50 cm of loamy sand with a 10 cm transition and 10 cm drainage layer. 3. The system was fully lined to prevent exfiltration. 4. The system was densely planted with indigenous plants to (a) maximise the volume of treated water (maintain infiltration capacity) and (b) maximise pollutant removal.

Little Stringybark Creek biofiltration project	Monash stormwater harvesting system
 	

3.3 KEY DESIGN ELEMENTS

The key components that need to be specified in the technical design are (Figure 3):

1. ***Inflow controls:*** These are structures that control both the inflow rate and the volume of stormwater into the plant/filter media zones of the biofilter. They incorporate the following:
    a. Inflow zone – controls the inflow rates into the system;
    b. Overflow – controls the volume of water that is treated; and
    c. Detention depth on top of the media – controls the volume of water that is detained for treatment (and thus determines the frequency of bypass).
2. ***Vegetation:*** Plants are crucial for both removal of nutrients and maintenance of hydraulic conductivity (K_s). They also contribute to the reduction of outflow volumes via evapotranspiration, which in turn can help the local microclimate. Vegetation should therefore be carefully specified according to the system objectives as well as the local climate.
3. ***Filter media:*** The purpose of the filter media is to both remove pollutants (through physical and chemical processes), as well as to support the plants and microbial community that are responsible for biological treatment. The filter media also reduces peak flows and outflow volumes by detaining and retaining runoff. The filter media has two layers:
    a. Soil- or sand-based media , where most treatment occurs; and
    b. Transition layer, which serves to prevent washout of filter media.

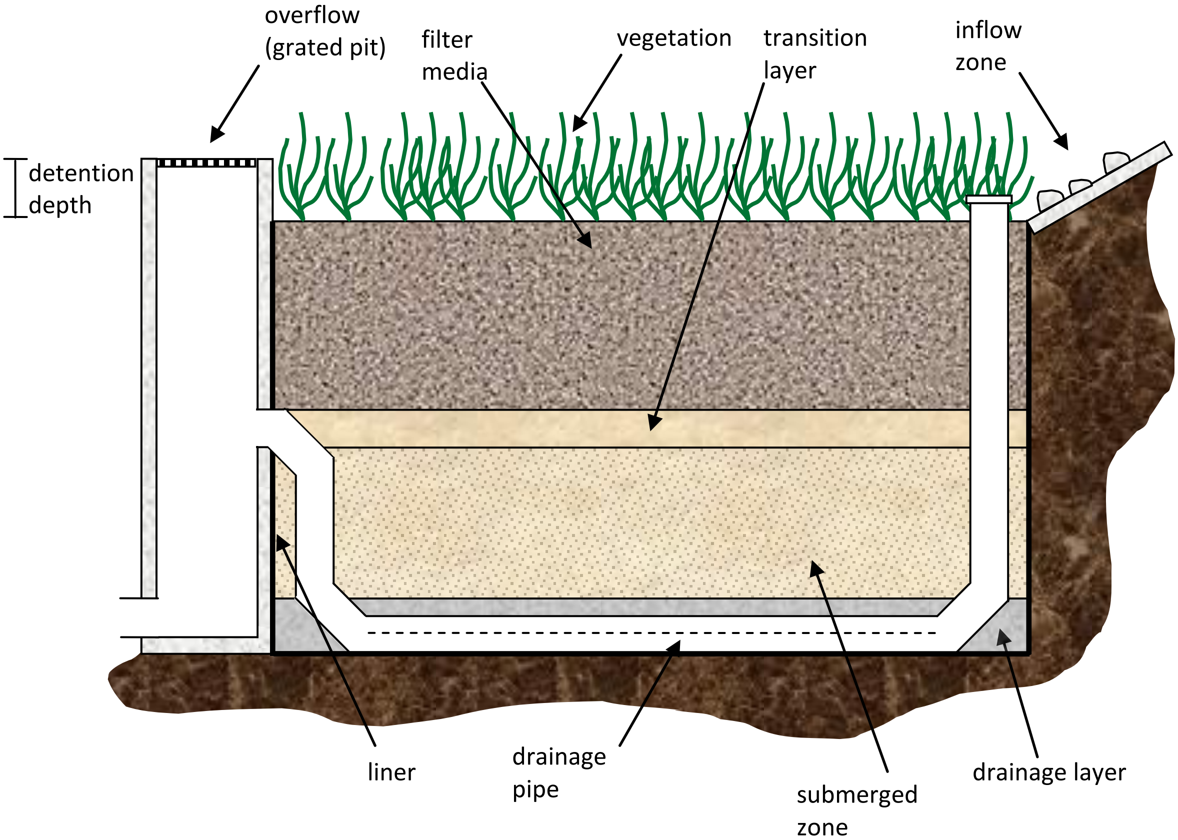


Figure 3. Main components of biofiltration systems that have to be specified.

4. ***Submerged zone***: This is comprised of a mix of medium-to-coarse sand and a carbon source, or gravel and a carbon source, and contains a permanent pool of water to support the plants and microbial community during extended dry spells, as well as to enhance nitrogen removal (because it promotes denitrification). This design element is highly recommended, however it is optional and its inclusion depends on the objectives of the system, as discussed in Section 3.2.1.

5. ***Outflow controls:*** These are structures that control how much water leaves the system, both through exfiltration (i.e., infiltration into surrounding soils) as well as direct outflow of through a drainage pipe. They incorporate the following:

    a. Liner – optional component, depending on site opportunities and constraints, which controls exfiltration of treated water into surrounding soils and/or intrusion of unwanted inflows from surrounding soils;

    b. Drainage layer – collects treated water at the bottom of the filter and conveys it to the drainage pipes; and

    c. Drainage pipes – quickly convey treated flows out of the system.

How these components are specified and arranged depends on the objectives of the system as well the site conditions (as discussed in Sections 3.2 and 3.2.1). The next section outlines possible system configurations, while details on how each component is designed are presented in Section 3.5.

3.4 KEY DESIGN CONFIGURATIONS

While there are many possible design variations for biofiltration systems, they may be broadly grouped into five main design configurations. The features of each of these configurations are described below, as well as suitable applications.

IMPORTANT!

- We ***strongly*** recommend the use of biofiltration systems that have a submerged zone ***wherever possible***. It has been shown that the treatment performance of biofiltration systems without submerged zones is significantly reduced after extended dry periods. However, the presence of a permanent pool of water, or submerged zone, at the bottom of the system helps to buffer against drying as well as maintain a healthy plant community throughout long dry spells.

3.4.1 Lined biofiltration system with submerged zone

This type of biofilter is optimal for the following cases:

- Sites where exfiltration is not possible (eg. where this is a need to protect built infrastructure, or interaction with a shallow groundwater table is undesirable);
- Climates that have very long dry spells (because the submerged zone will act as a water source to support the plants and microbial community for over five weeks with no rainfall); and
- If systems are designed for NO_x removal or if receiving waters are highly sensitive to Cu or Zn.

Two possible configurations of this type of the system are given in Figure 4. The top biofiltration system contains a submerged zone created in a sand layer while the bottom system contains a submerged zone created in a gravel layer.

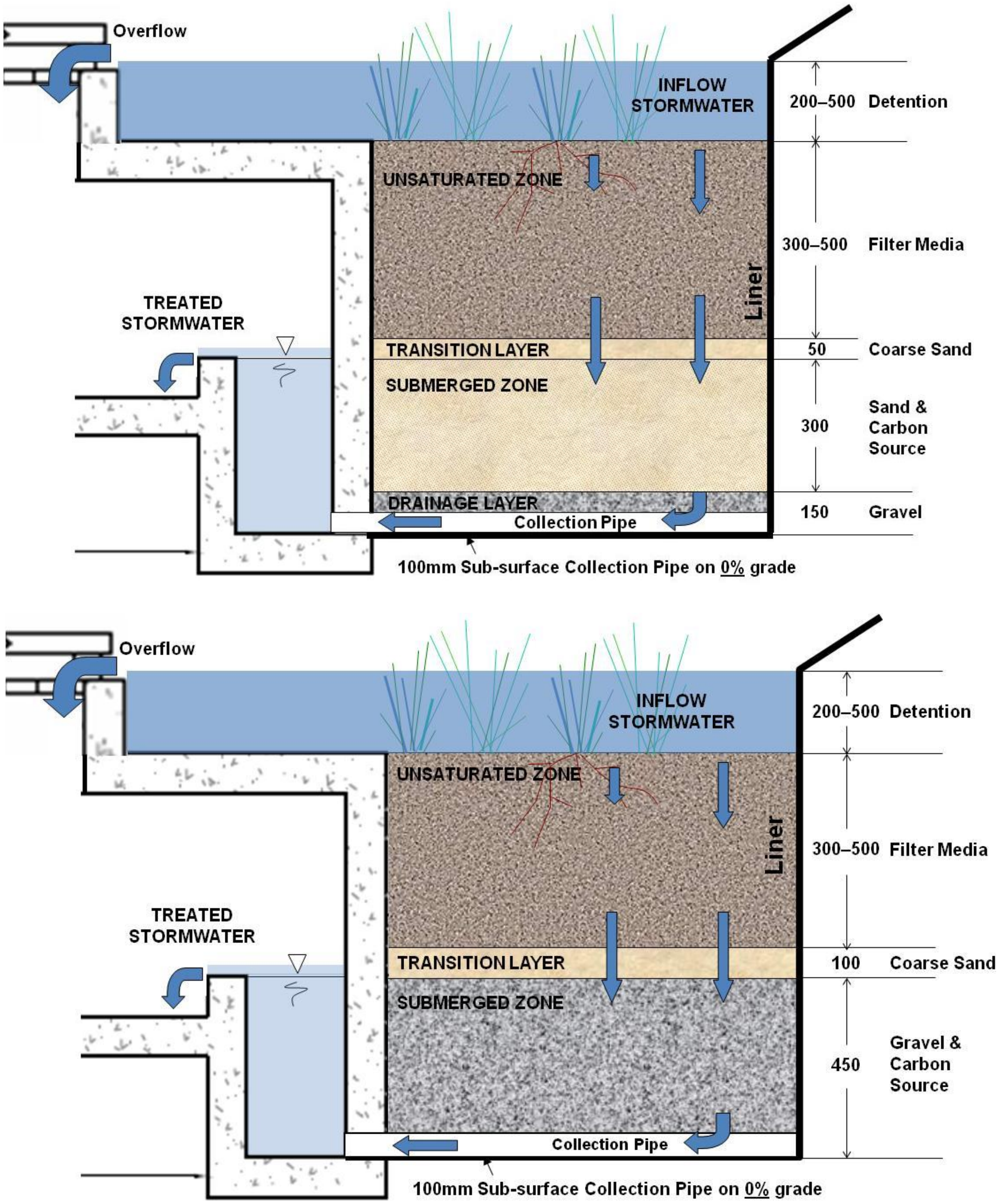


Figure 4. Lined biofiltration system with submerged zone comprised of sand (top) and gravel (bottom).

It should be noted that, in small systems, the outflow structure for treated water should be made using a simple pipe with two elbows (designed as a raised outlet), while overflow structures could be simple raised pits located within the detention pond (as in Figure 3). Only large systems require more complex outflow structures, as presented in Figure 4.

These systems can be shaped to fit into the available space and therefore can be built as simple trenches or basins. They can also be constructed as "on-line", conveyance (commonly referred to as biofiltration swales) or "off-line", non-conveyance (known generally as biofiltration basins) systems. Biofiltration swales have an additional component that must be specified – a conveyance channel.

As such, they also generally need to be able to withstand higher flow velocities, which needs to be considered when designing the inflow and overflow zones. However, all other design elements are specified in the same way as for biofiltration basins.

3.4.2 Lined standard biofiltration system

This type of biofilter, whose possible configuration is illustrated in Figure 5, should be used for the following situations:

- Sites where exfiltration is not possible (eg. where this is a need to protect built infrastructure or avoid interactions with groundwater);
- Climates that do not experience long dry spells – defined as no inflow into the ***system for three continuous weeks*** (Note: biofilters will receive inflows even during very small events due to their very small size relative to the catchment); and
- If systems are designed for stormwater harvesting where nitrogen removal is not critical (eg. for irrigation applications).

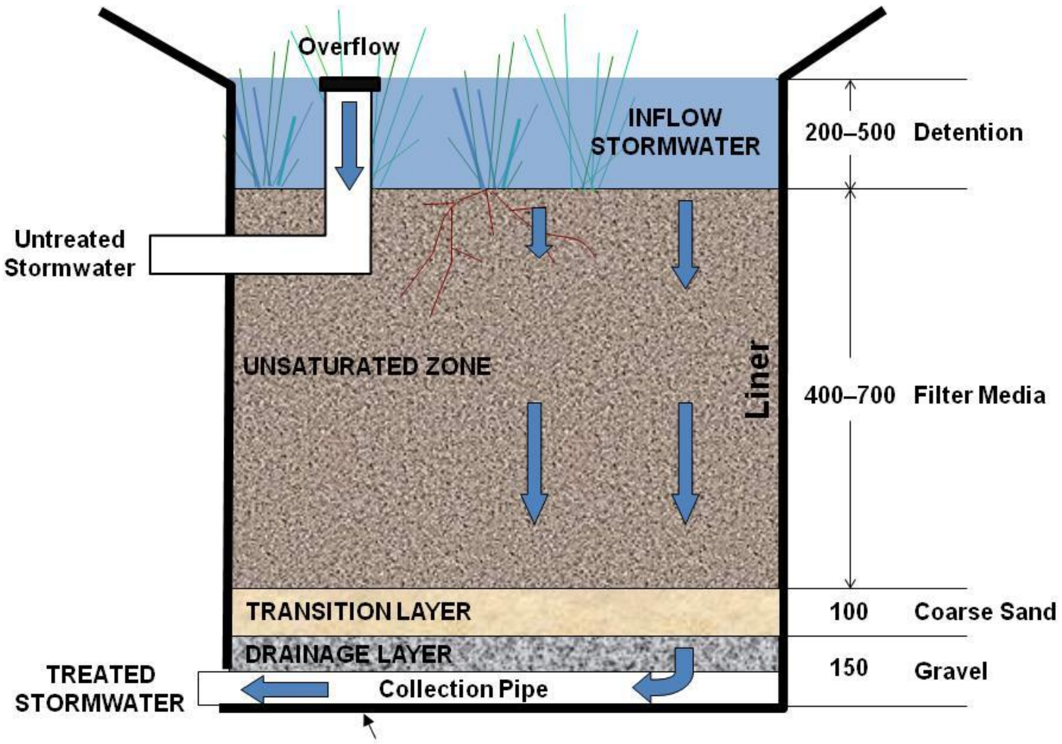


Figure 5. Lined standard biofiltration system.

These systems can be shaped to fit into the available space and therefore can be built as simple trenches or basins. They can also be constructed as "on-line", conveyance (commonly referred to as biofiltration swales) or "off-line", non-conveyance (known generally as biofiltration basins) systems. Biofiltration swales have an additional component that must be specified – a conveyance channel. As such, they also generally need to be able to withstand higher flow velocities, which needs to be considered when designing the inflow and overflow zones. However, all other design elements are specified in the same way as for biofiltration basins.

3.4.3 Unlined standard biofiltration system

This type of biofilter (Figure 6), along with the system described in Section 3.4.5, are the simplest forms of biofiltration systems to design and build. This system is highly recommended for:

- Sites where little or no exfiltration is allowed and the hydraulic conductivity of the surrounding soils is at least one order of magnitude lower than the filter media;
- Climates that do not experience long dry spells – defined as no inflow into the ***system for three continuous weeks*** (Note: biofilters will receive inflows even during very small events due to their very small size relative to the catchment, therefore modelling is required to ensure that this criteria is met); and
- Systems that are NOT designed for stormwater harvesting.

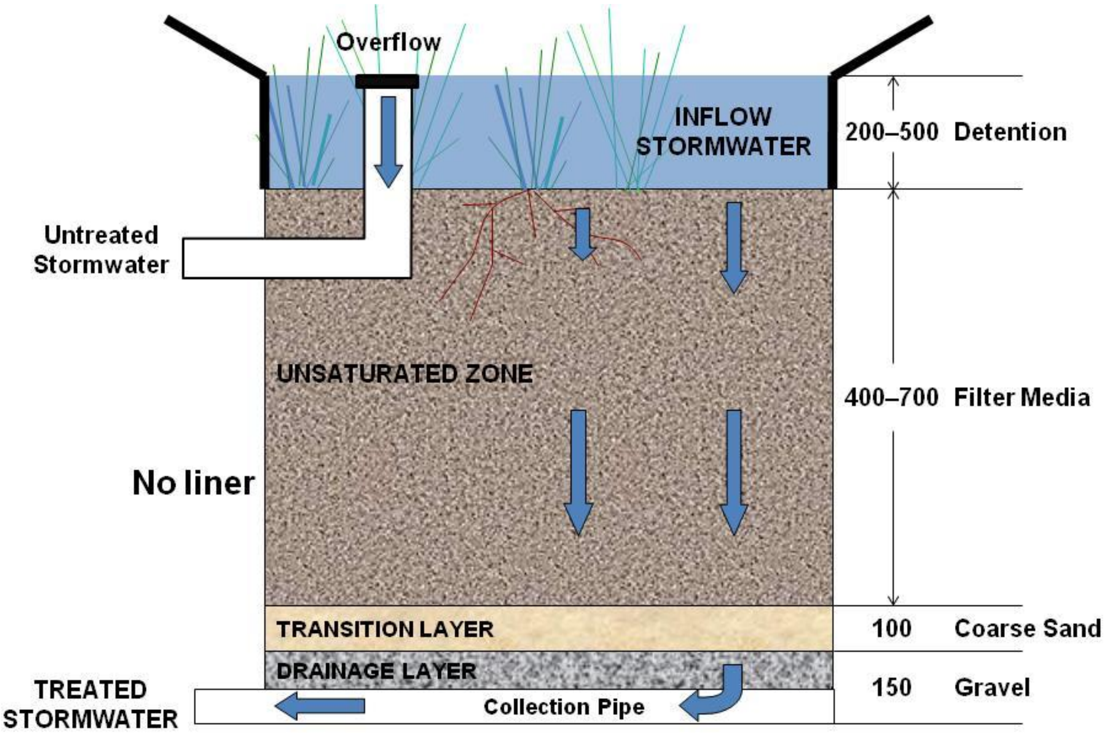


Figure 6. Unlined standard biofiltration system.

Figure 6 illustrates this type of system with a collection pipe at the bottom of the drainage layer, however another variation is also possible, where the collection pipe is raised above the base of the drainage layer (this is discussed in further detail in Section 3.5.10).

It should be noted that, where there are assets that need to be protected, one or more sides of the system can be lined. Suitable areas for unlined biofiltration systems include those where soil salinity might initially be considered a risk (eg. western Sydney, Wagga Wagga), as it has been demonstrated that the dominant flow path is from the biofilter to the surrounding soils, thereby preventing salt from entering the system (Deletic & Mudd, 2006).

These systems can be shaped to fit into the available space and therefore can be built as simple trenches or basins. They can also be constructed as "on-line", conveyance (commonly referred to as biofiltration swales) or "off-line", non-conveyance (known generally as biofiltration basins) systems. Biofiltration swales have an additional component that must be specified – a conveyance channel. As such, they also generally need to be able to withstand higher flow velocities, which needs to be considered when designing the inflow and overflow zones. However, all other design elements are specified in the same way as for biofiltration basins.

3.4.4 Unlined biofiltration system with submerged zone

This configuration is suitable when exfiltration is allowed but the local climate is very dry (i.e., plant survival may be uncertain). However, the benefit of exfiltration will be very limited as it can only occur through the sides of the system (Figure 7). These systems are not recommended for stormwater harvesting applications.

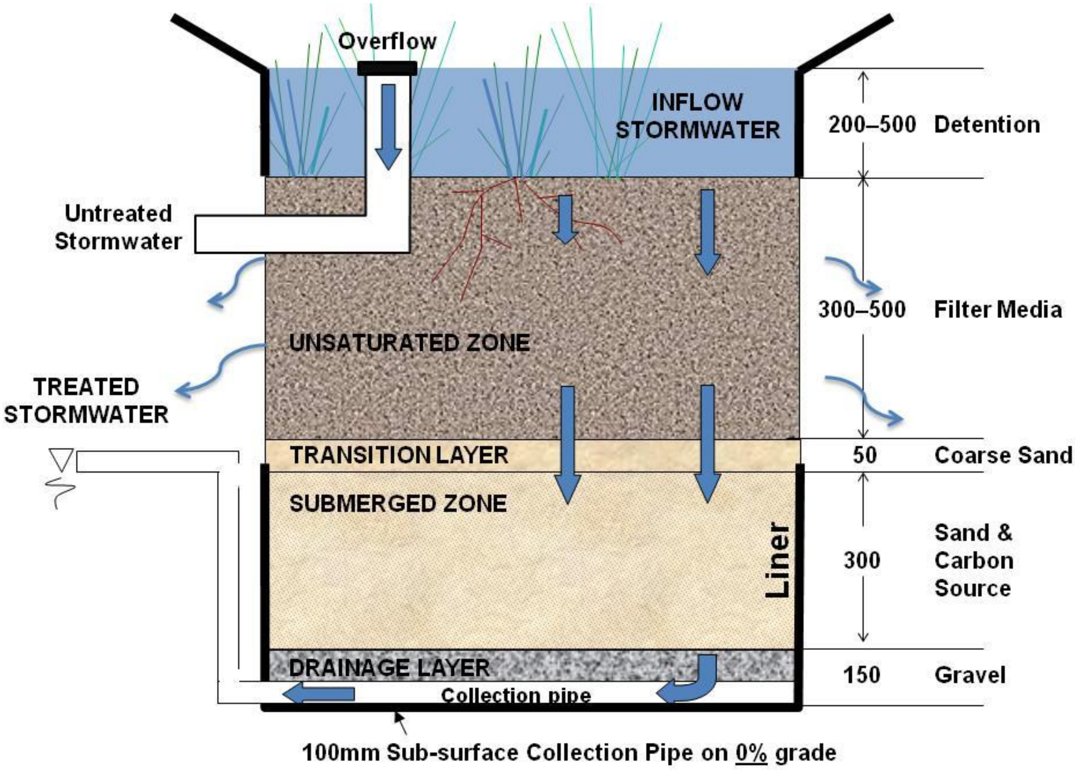


Figure 7. Unlined biofiltration basin with submerged zone

It is important to note that, even though this system is defined as unlined, the bottom and sides of the submerged zone still need to be lined in order to maintain a permanent pool of water. As discussed in previous sections, liners can be combined in different ways. For example, it may be desirable to line just one side of the system to protect a nearby asset (eg. side butting up against road).

These systems can be shaped to fit into the available space and therefore can be built as simple trenches or basins. They can also be constructed as "on-line", conveyance (commonly referred to as biofiltration swales) or "off-line", non-conveyance (known generally as biofiltration basins) systems. Biofiltration swales have an additional component that must be specified – a conveyance channel. As such, they also generally need to be able to withstand higher flow velocities, which needs to be considered when designing the inflow and overflow zones. However, all other design elements are specified in the same way as for biofiltration basins.

3.4.5 Bio-infiltration system

This type of biofilter is a hybrid of the better known standard biofiltration systems and infiltration systems (Figure 8). It is highly recommended for:

- Sites where exfiltration is allowed;
- Providing both water quality improvement and reduction in runoff volumes; and
- Systems that are NOT designed for stormwater harvesting.

The only difference between standard biofiltration and bio-infiltration systems is that bio-infiltration systems do not contain a collection pipe in the drainage layer. Instead, this layer doubles as a detention layer where treated water is temporarily stored before exfiltrating to the surrounding soils. This configuration will help to improve the hydrology of receiving waterways by infiltrating stormwater at or near the source. Bio-infiltration systems are preferable to standard, non-vegetated infiltration systems because they provide for superior treatment, particularly with respect to nutrient removal. ***They are therefore highly recommended, particularly if the surrounding soils have a good infiltration capacity.***

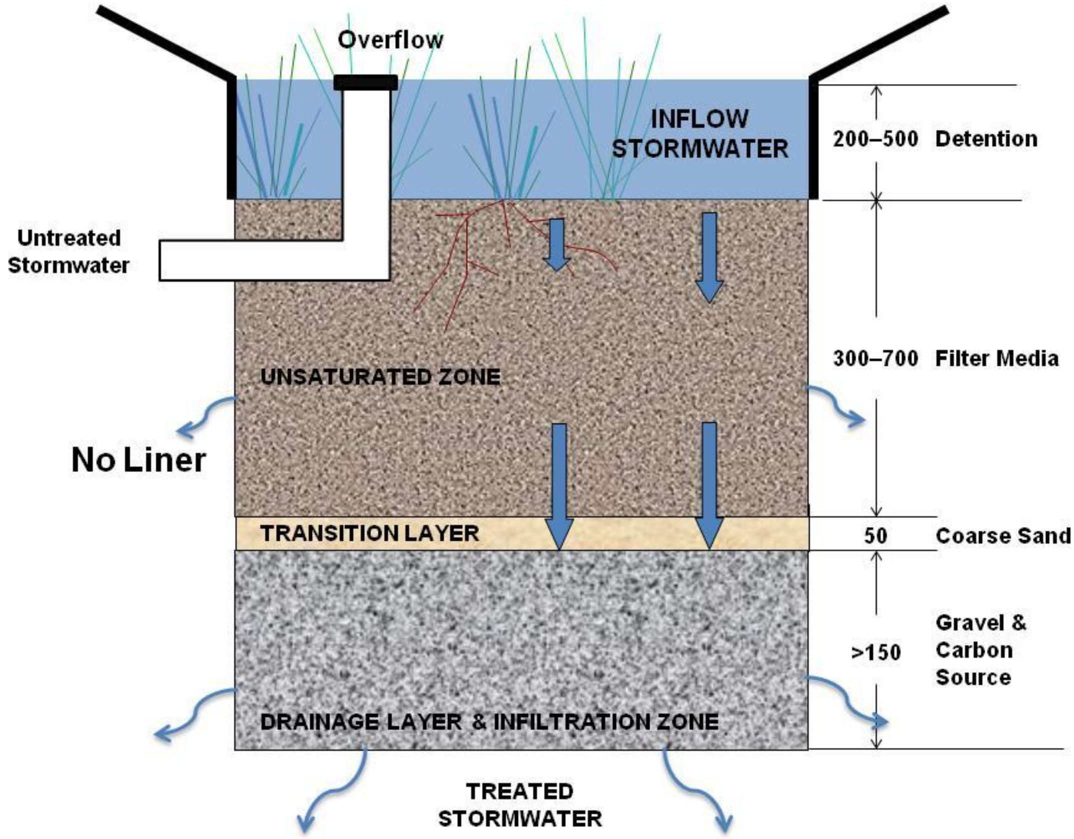


Figure 8. Schematic of a bio-infiltration system.

It is important to note that bio-infiltration systems can still have a submerged zone. In fact, in areas where the soils are clay, a submerged zone will automatically be created as the exfiltration rate is likely to be low so that the system rarely completely drains. However, in areas where the soils have a high drainage rate, a two-component configuration can be adopted, as shown in Figure 9.

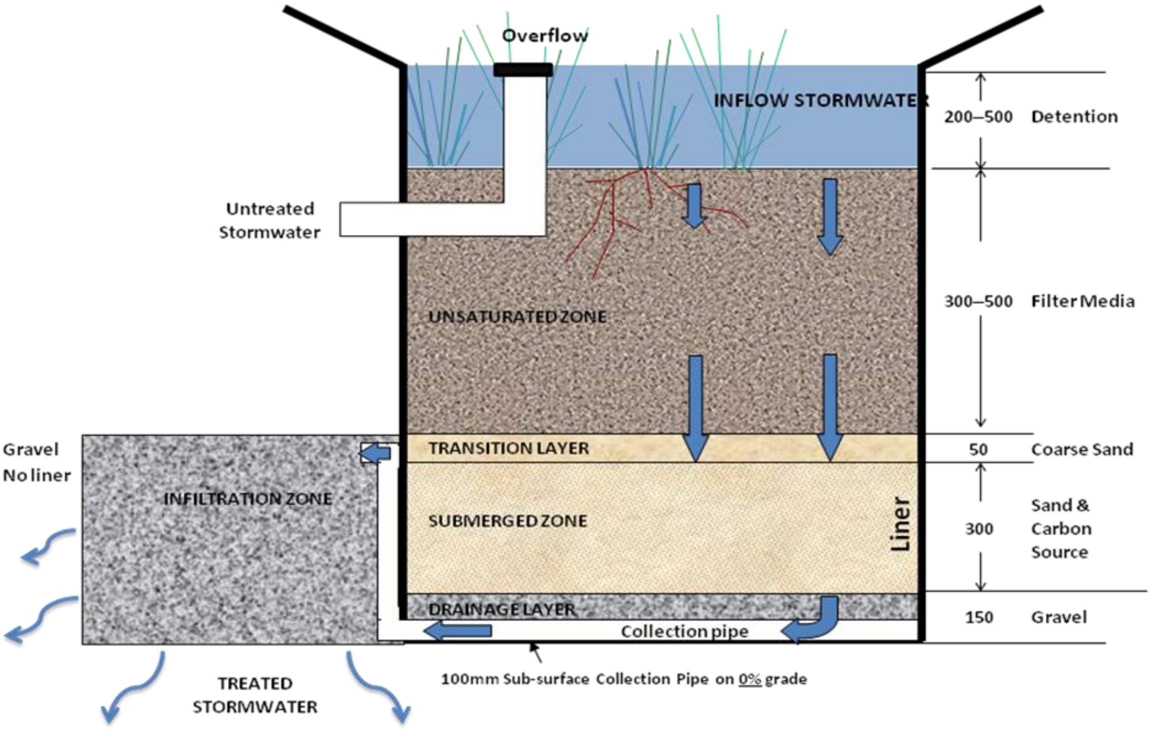


Figure 9. Schematic of a bio-infiltration system containing a submerged zone.

These systems can be shaped to fit into the available space and therefore can be built as simple trenches or basins. They can also be constructed as “on-line”, conveyance (commonly referred to as bio-infiltration swales) or “off-line”, non-conveyance (known generally as bio-infiltration basins) systems. Bio-infiltration swales have an additional component that must be specified – a conveyance channel. As such, they also generally need to be able to withstand higher flow velocities, which needs to be considered when designing the inflow and overflow zones. However, all other design elements are specified in the same way as for bio-infiltration basins.

3.5 DESIGN PROCEDURE

The general procedure for the design of a biofiltration system is illustrated in Figure 10. The components that control the volume of water that can be treated (filter surface area, extended detention depth, filter media hydraulic conductivity) and the level of treatment (filter media characteristics, vegetation, presence/absence of a submerged zone) are specified first, then the inflow and outflow controls are designed.

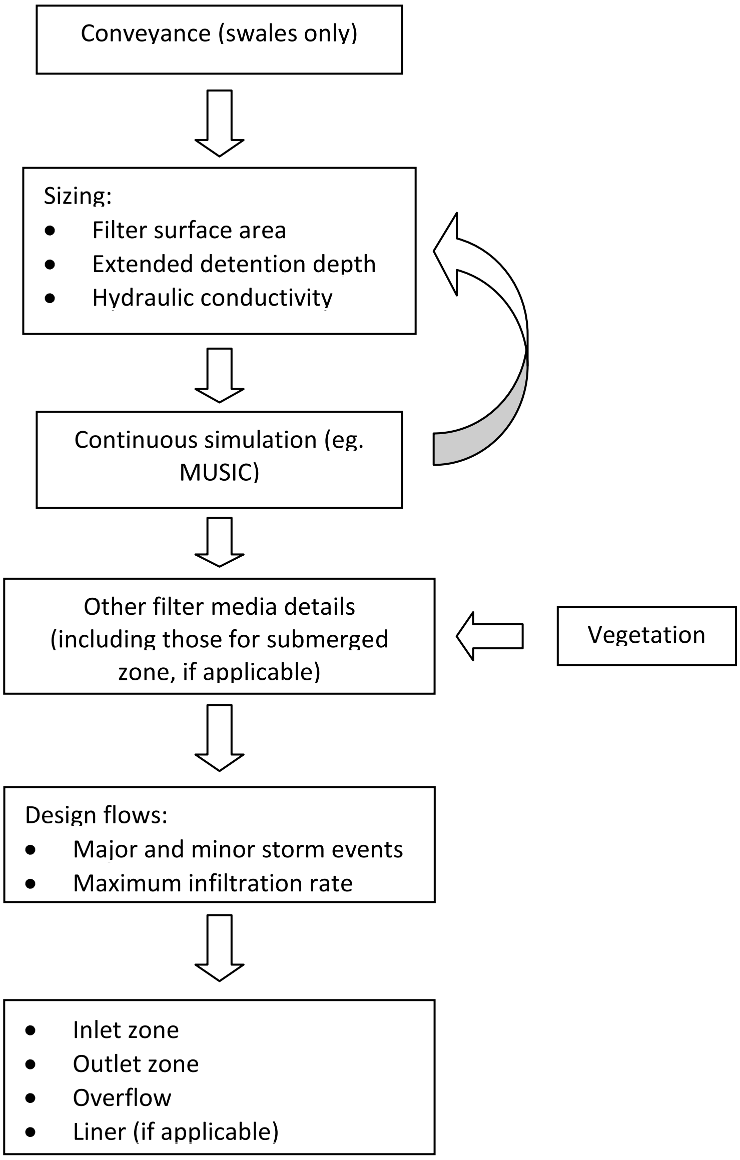


Figure 10. Procedure for specifying the components of a biofiltration system.

The following sections briefly describe the design procedure for each functional component of a biofiltration system. Where further details or specific expertise is required, this is highlighted.

3.5.1 Conveyance

The swale component needs to be designed first when designing a biofiltration swale, as it will determine the available dimensions for the biofiltration component. Refer to local engineering procedures for the design procedure and guidance on suitable flow velocities.

3.5.2 Sizing

The required size of a biofiltration system could be determined using performance curves such as those provided in the Water Sensitive Urban Design Technical Design Guidelines for South East Queensland (BCC & MBWCP, 2006), where the surface area can be selected according to the extended detention depth and desired pollutant removal performance. Note that performance curves representative of the local climate should be used; similar curves exist for most States and

Territories. However, the volumetric treatment (infiltration) capacity of a biofiltration system is also a function of the hydraulic conductivity of the filter media, and so this should also be considered in determining the size.

As a starting point, a biofiltration system with a surface area that is 2% of the impervious area of the contributing impervious catchment, an extended detention depth of 100 – 300 mm and a hydraulic conductivity of 100 – 300 mm/hr would be a fairly typical design in order to meet regulatory load reduction targets for a temperate climate. The hydraulic conductivity may need to be higher in tropical regions in order to achieve the required treatment efficiency using the same land space and detention depth (i.e., ensuring that the proportion of water treated through the media meets requirements). Where one of these design elements falls outside the recommended range, the treatment capacity can still be met by offsetting another of the design elements.

For example, if there is a desire to use a particular plant species (landscape consideration) but that plant requires wetter conditions than can be provided with a filter media that drains at 200 mm/hr, use of a slower draining filter media to support healthy plant growth may be feasible if the surface area of the system can be increased to compensate.

This preliminary design should be refined and adjusted as necessary using a continuous simulation model. See Appendix B for guidance on sizing using MUSIC.

☝ DESIGN TIPS

- Design and model based on K_s of ***half*** the design value (to allow for gradual reduction in the hydraulic conductivity of the filter media over time)
- The bigger the system relative to its contributing catchment, the greater the volumetric losses will be, however this may require specification of different planting zones to accommodate different wetting and drying conditions
- Ideas to increase effective size
  - Break up the catchment if space is limited
  - Increase ponding depth (use novel design to ensure safety)
- Consider hydrologic effectiveness during design

3.5.3 Filter Media Selection

1. Specify filter media type

Suitable filter media should be selected using the criteria described in FAWB's Guidelines for Filter Media in Biofiltration Systems (see Appendix C version 3.01, noting that the ***most recent version*** of these guidelines should always be used). While other filter media types may be suitable, they should not be used unless their long-term hydraulic and pollutant removal performance has been tested ***prior*** to installation.

Guidance on additives:

- Exploded minerals

Use of exploded minerals, such as vermiculite and perlite, to boost the cation exchange capacity of the filter media have not been shown to have any short-term benefits in terms of pollutant removal, largely because the pollutants they are designed to target (heavy metals) are already effectively removed by all filter media types suitable for biofiltration systems. While vermiculite and perlite may play a role in the long-term retention of heavy metals, this can only be demonstrated through long-term testing and so remains a hypothesis. However, the porosity and stable structure of these materials has been shown to be useful in maintaining the infiltration capacity of the filter media during the establishment phase (Hatt *et al.*, 2009). For this reason, incorporation of exploded minerals into the filter media (10 – 20% by volume) could be considered. Note that mixing would need to be carried out on-site due to the different densities of the materials and that a 50 mm 'cap' of plain filter media should be used as exploded minerals float.

- Organic matter

It may be desirable to increase the organic content eg. to support particular plant growth (landscape requirements). In such cases, it is important to ensure that the nutrient content of the organic matter is kept low to avoid nutrient leaching (see Appendix C). It may also be appropriate to provide a layered structure, where only the top layers of the filter media have a higher organic content.

- Commercial products

Commerically available products with high adsorption capacities that target specific pollutants, such as activated carbon (heavy metals) and Phoslock (phosphorus), might also be considered, but the benefits of these products should be weighed up against their cost, durability and sustainability (eg. manufacture, transport).

DESIGN TIPS

- Typical K_s range: 100 – 400 mm/hr
- Must demonstrate prescribed hydraulic conductivity
- Test to ensure the filter media will remain permeable under compaction
- <3% silt and clay
- Does not leach nutrients
- Ensure EC and pH is in the range for healthy plant growth

SUSTAINABILITY TIP

- In some areas, it may be feasible to construct a filter medium from the *in situ* soil, although some amendments are likely to be required, to ensure that the resulting medium meets the required specifications (see Appendix C).

2. Specify filter media depth

The depth of the filter media can vary and will be partially determined by site conditions and landscape requirements. As a guide, the typical filter depth range is 400 – 600 mm, excluding the transitions and drainage layers. The minimum depth required to support plant growth (groundcovers, grasses, sedges, rushes, small shrubs) and ensure adequate removal of heavy metals (Hatt *et al.*, 2008) is 300 mm, while a depth of 800 mm is recommended for tree planting.

3.5.4 Submerged Zone

1. Submerged zone material

The submerged zone should be comprised of a mix of medium-to-coarse sand and carbon or a mix of fine gravel and carbon. The carbon source should be a mix of 5% mulch and 5% hardwood chips (approximately 6 mm grading), by volume.

2. Submerged zone depth

A depth of 450 mm has been shown to be optimal (Zinger *et al.*, 2007), however the feasibility of this will be determined by site conditions. A minimum of 300 mm is required for this zone to be effective.

IMPORTANT!

- A submerged zone with a depth of 300 mm will protect against drying for up to ***five weeks of continuous dry weather***. For climates where longer dry periods are likely, the depth of the submerged zone should be increased by ***120 mm for every additional week of dry weather***. Where this is not feasible, the submerged zone should be as deep as possible and filled up as required, either via surface irrigation or direct filling. For example, if the maximum possible depth is 300 mm but the biofilter is likely to experience seven weeks of dry weather (so the ideal depth is 540 mm), the submerged zone would need to be filled after five weeks.
- A 50 mm layer of plain sand i.e., not mixed with mulch and woodchips, should separate the filter media and the submerged zone to prevent the filter media from becoming permanently saturated, which may lead to leaching of pollutants, particularly nutrients.

DESIGN TIPS

- Since the invert of the outlet pipe in a biofilter containing a submerged zone is raised above the bottom of the system, this can assist in achieving a suitable filter depth where the available depth to the underdrain invert is limited.
- Typical recipe for submerged zone filter media (per 100 L):

  98 L sand (by volume)

  500 g readily biodegradeable material such as sugar-cane mulch (preferably low in nitrogen and phosphorus)

  1.5 kg hardwood chips

SUSTAINABILITY TIP

- Recycled timber (must not be chemically treated) or hardwood chips from sustainable sources (eg. certified plantations) should be specified for the carbon source.

3.5.5 Design Flows

Estimate the following design flows:

1. The minor storm event (5-year ARI for temperate climates, 2-year ARI for tropical climates, or according to local regulations), to size the inlet zone and overflow structure, and to check scouring velocities;
2. The major storm event (100-year ARI for temperate climates, 50-year ARI for tropical climates, or according to local regulations), if larger storms will enter the biofiltration system (i.e., are not diverted upstream of the system), to check that erosion, scour or vegetation damage will not occur; and
3. The maximum infiltration rate through the filter media, to size the underdrain.

For small systems (i.e., contributing catchment area <50 ha), use the Rational Method to estimate minor and major flows. For large systems (i.e., contributing catchment area >50 ha), use runoff routing to estimate minor and major flows.

3.5.6 Inlet Zone

Inflows to biofiltration systems may be concentrated (via a piped or kerb and channel system) or distributed (surface flow). It is important to deliver inflows so that they are uniformly distributed over the entire surface area and in a way that minimises flow velocity i.e., avoids scour and erosion, and maximises contact with the system for enhanced treatment. Therefore, distributed inflows are the preferred option, however this is not always possible. In the case of biofiltration basins, inflows are almost always concentrated. Regardless, multiple inlet points can, and should, be used wherever possible.

Refer to local guidelines for design procedures for inlet zones. Refer also to local council regulations to ensure that their requirements for flow widths, etc. are met.

If inflows enter the biofiltration system over a flush kerb (distributed system), an area is needed for coarse sediments to accumulate (to avoid buildup and subsequent unintended diversion of flows around the system). This can be achieved by having a step down, where the vegetation and the filter surface are approximately 40 – 50 mm and 100 mm below the hard surface, respectively, to prevent sediment accumulation occurring upstream of the system (Figure 11).

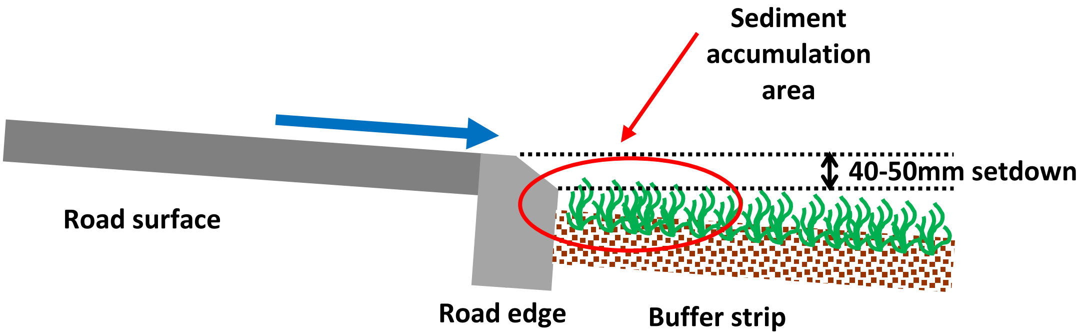


Figure 11. Edge detail of biofiltration inlet zone showing setdown (source: Melbourne Water, 2005).

If the entry point(s) for flows are concentrated, an energy dissipator and flow spreader to reduce flow velocities protect against erosion will generally be required. Options for energy dissipation include:

a) Rock beaching/impact type energy dissipation – where rocks (several of which are as large as the pipe diameter) are placed in the flow path to reduce velocities and spread flows (Figure 12 & Figure 13);

b) Dense vegetation – technical manuals suggest that planting can cope with <0.5 m/s for minor flows and <1.0 m/s for 100-year ARI flows (Figure 13); and

c) Surcharge pit – where piped inflows can be brought to the surface. Surcharge pits need to have drainage holes at the case to avoid standing water (Figure 14) and must be accessible so that any accumulated sediment can be removed. A removable geotextile layer aids cleaning of accumulated sediment (Figure 14).

DESIGN TIP

- Consider the need for maintenance access when designing energy dissipation structures.

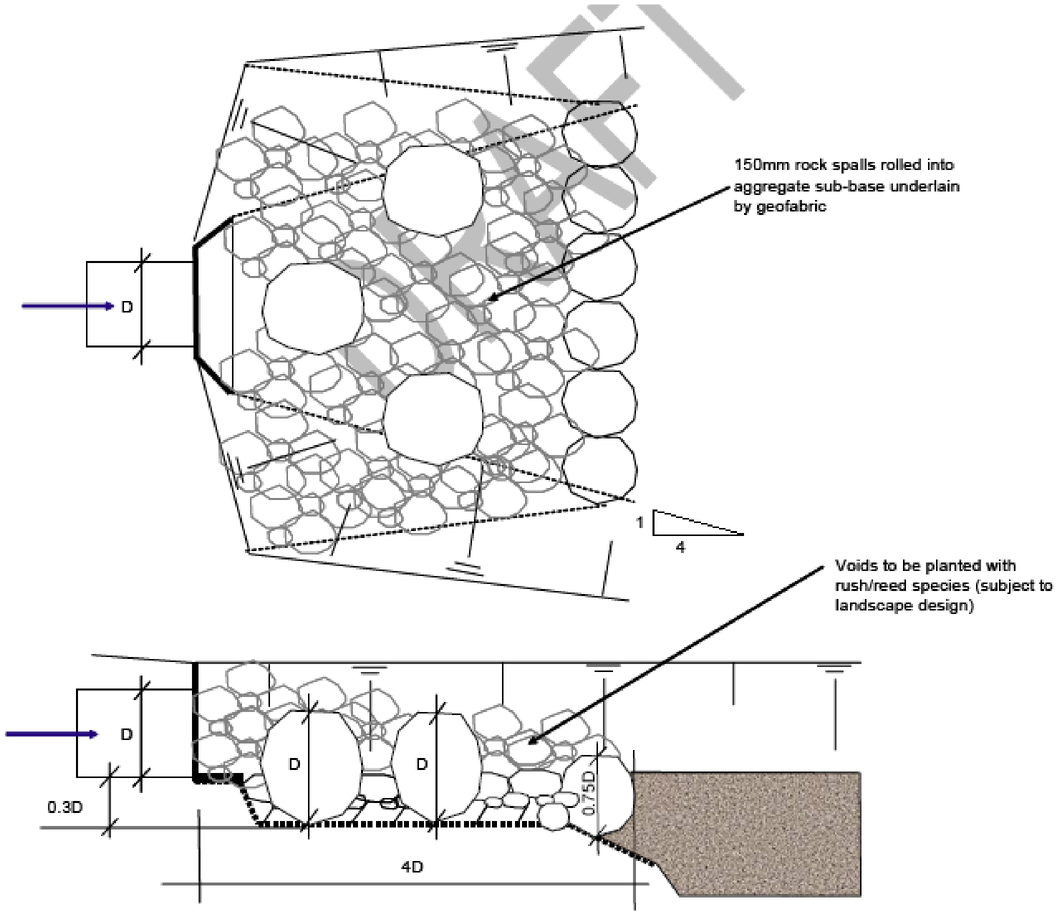


Figure 12. Rock beaching for scour protection in a biofilter receiving piped flows, where D represents the pipe diameter (source: BCC & MBWCP, 2006).

Figure 13. A rock apron (left) and dense vegetation (right) at the inlet to a biofilter can be used reduce flow velocities and prevent scour and erosion damage.

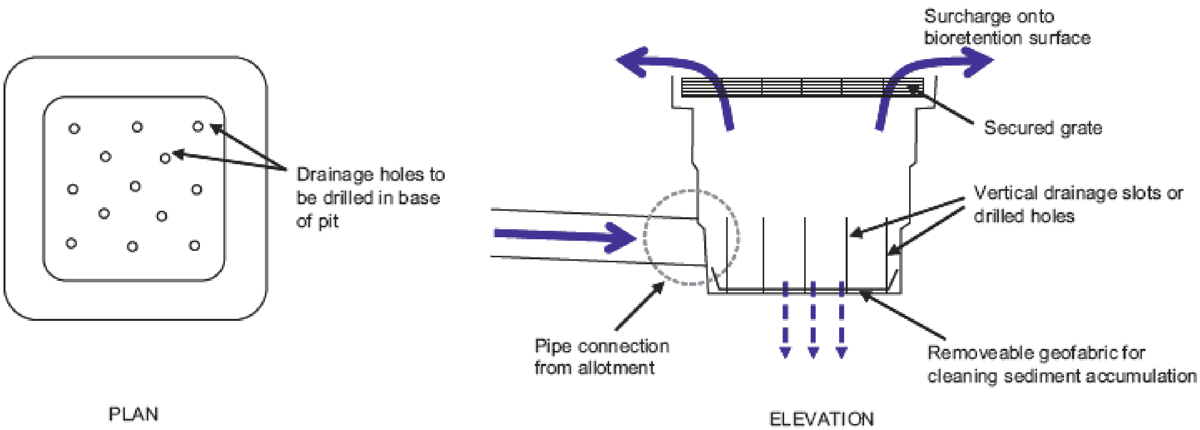


Figure 14. Surcharge inlet pit containing drainage holes at base of pit and removable geotextile layer for cleaning accumulated sediment (source: Melbourne Water, 2005).

IMPORTANT!

- The inlet zone needs to be designed by a hydraulic engineer.

3.5.7 Overflow Zone

Design of the overflow zone is different for biofiltration basins and biofiltration swales. Where possible, minor floods should be prevented from entering a biofiltration basin to prevent scour and erosion, however the feasibility of this will depend on site conditions. Conversely, biofiltration swales are designed to convey at least the minor flood, therefore overflow provisions must be sized accordingly.

Basins. Where inflows enter the basin via a kerb and channel system, an normal side entry pit may be located immediately downstream of the inlet to the basin (Figure 15), to act as a bypass. When the level of water in the basin reaches the maximum extended detention depth, flows in the kerb will simply bypass the basin and enter the downstream side entry pit. This pit should be sized to convey the minor flood to the conventional stormwater drainage network.

Where it is not possible to use a conventional side entry pit, a grated overflow pit should be located in the biofiltration basin and as close to the inlet as possible to minimise the flow path length for above-capacity flows (thus reducing the risk of scouring, Figure 15).

Figure 15. A side entry pit downstream of a biofiltration tree pit accepts high flows that bypass the tree pit (left) while a grated inlet pit close to the inlet of a biofiltration basin conveys above-design flows to the conventional drainage network (right).

DESIGN TIPS

- Where a grated overflow pit in the basin is used, flow velocities in the basin need to be checked to avoid scour of the filter media and vegetation. Technical manuals suggest planting can cope with <0.5 m/s for minor flows and <1.0 - 1.5 m/s for 100-year ARI flows.
- Ensure that the full extended detention depth is provided by setting the level of the overflow at the same level as the maximum ponding depth.

Swales. Overflow pits are required where the flow capacity of the swale is exceeded; these are generally located at the downstream end of the swale, but may need to be staggered along the system (creating a series of segments along the swale), depending on the length of the swale. Refer to local engineering procedures for guidance on locating overflow pits.

IMPORTANT!

- The overflow zone needs to be designed by a hydraulic engineer.

3.5.8 Transition Layer

1. Transition layer material

The transition layer material shall be a clean, well-graded sand material containing <2% fines. To avoid migration of the filter media into the transition layer, the particle size distribution of the sand should be assessed to ensure it meets 'bridging criteria', that is, the smallest 15% of the sand particles bridge with the largest 15% of the filter media particles (Water by Design, 2009b; VicRoads, 2004):

D_{15} (transition layer) ≤ 5 x D_{85} (filter media)

where: D_{15} is the 15th percentile particle size in the transition layer material (i.e., 15% of the sand is smaller than D_{15} mm), and
D_{85} is the 85th percentile particle size in the filter media.

A dual-transition layer, where a fine sand overlays a medium-coarse sand, is also possible. While it is acknowledged that this can increase the complexity of the construction process, testing indicates that a dual-transition layer produces consistently lower levels of turbidity and concentrations of suspended solids in treated outflows than a single transition layer. Therefore, it is recommended that this design be specified for stormwater harvesting applications (to enable effective post-treatment disinfection) and where minimising the risk of washout during the establishment period is of particular importance.

2. Transition layer depth

The transition layer depth shall be a minimum of 100 mm.

Note: The transition layer can be omitted from a biofiltration system provided the filter media and drainage layer meet the following criteria as defined by the Victorian Roads *Drainage of Subsurface Water from Roads - Technical Bulletin No 32* (VicRoads, 2004):

D_{15} (drainage layer) ≤ 5 x D_{85} (filter media)

D_{15} (drainage layer) = 5 to 20 x D_{15} (filter media)

D_{50} (drainage layer < 25 x D_{50} (filter media)

D_{60} (drainage layer) < 20 x D_{10} (drainage layer)

These comparisons are best made by plotting the particle size distributions for the filter media and gravel on the same soil grading graphs and extracting the relevant diameters (Water by Design, 2009).

3.5.9 Drainage Layer

1. Drainage layer material

The drainage layer material is to be clean, fine gravel, such as 2 – 5 mm washed screenings. The drainage layer is to be clean, fine gravel, such as a 2 – 5 mm washed screenings. Bridging criteria should be applied to avoid migration of the transition layer into the drainage layer (Water by Design, 2009b; VicRoads, 2004):

D_{15} (drainage layer) ≤ 5 x D_{85} (transition layer)

where: D_{15} (drainage layer) is the 15th percentile particle size in the drainage layer material (i.e., 15% of the gravel is small than D_{15} mm), and
D_{85} (transition layer) is the 85th percentile particle size in the transition layer material.

SUSTAINABILITY TIP

- Materials such as crushed recycled concrete may also be appropriate for the drainage layer, however they ***must*** be washed i.e., not contain fine particles that could wash out of the drainage layer, negating solids removal and/or potentially block underdrain pipes.

2. Drainage layer depth

For standard biofiltration systems (i.e., no submerged zone):

Where there is an underdrain present, the depth of the drainage layer will be determined by the underdrainage pipe diameter, minimum pipe cover, the slope of the underdrain and the length of system being drained. In general, the minimum pipe cover of the gravel drainage layer should be 50 mm (to avoid ingress of the sand transition layer into the pipe). For example, for a biofiltration system with an underdrainage pipe diameter of 100 mm that is 10 m long and on a slope of 1%, the drainage layer would be 150 mm deep at the upstream end and 300 mm deep at the downstream end (Figure 16).

Where there is no underdrain, the gravel drainage layer acts also as a 'storage zone', to permit water to be stored during a storm event, and then released into underlying soils via exfiltration. In this case, the depth of the gravel layer should be determined using modelling, to determine the required depth to ensure required targets (eg. reductions in pollutant load, runoff volume and/or frequency) are met (Figure 17). As a general guide, the storage zone needs to be at least as large as the extended detention volume, and preferably larger, to ensure that the filter media does not become saturated after consecutive rainfall events (i.e., where the storage zone has not emptied between rainfall events).

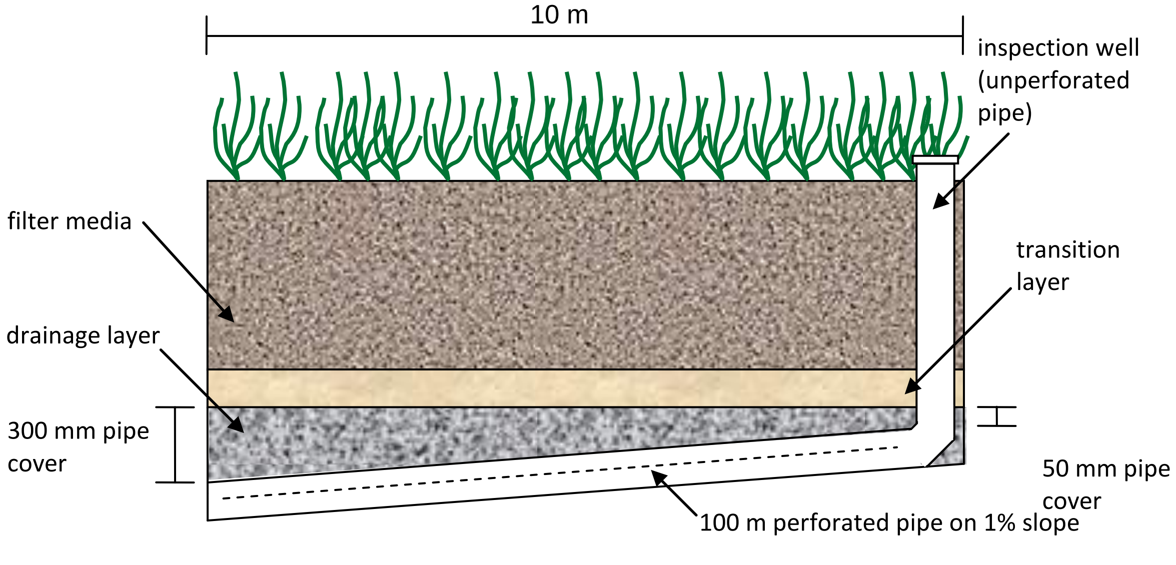


Figure 16. Long-section of a biofiltration system showing variable drainage layer depth.

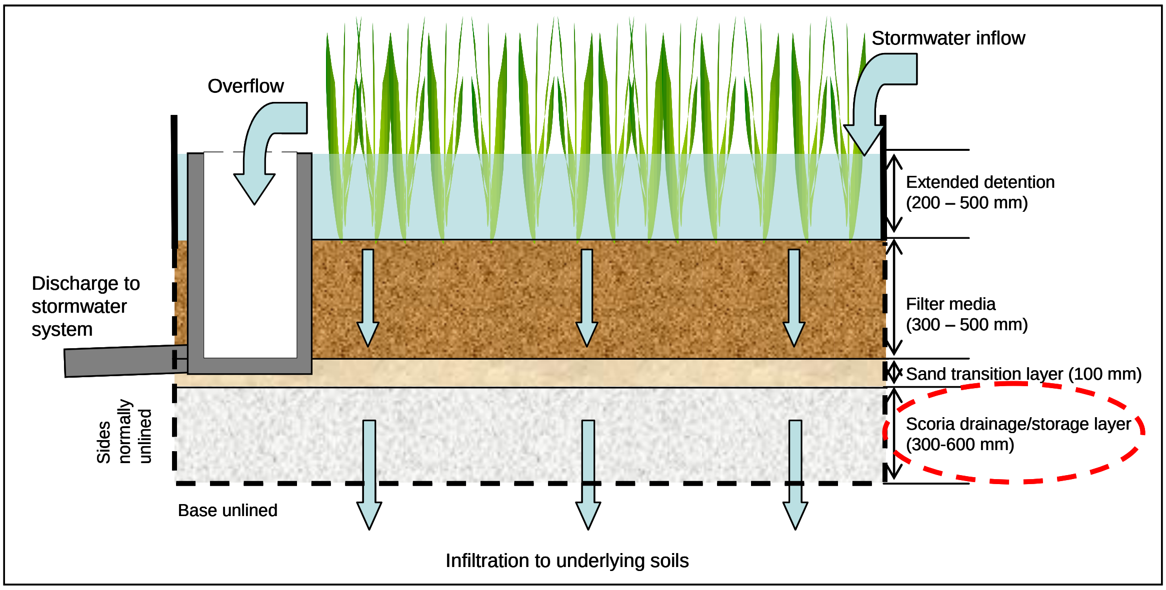


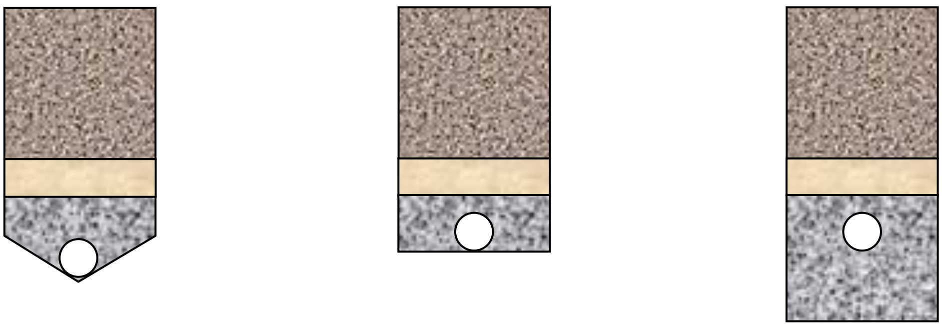
Figure 17. Use of the gravel drainage layer as a storage zone in a biofiltration system without underdrain.

For biofiltration systems containing a submerged zone:

The depth of the drainage layer in a biofiltration system with a submerged zone will be determined by the underdrainage pipe diameter and minimum pipe cover. In general, where the submerged zone material is sand-based, the minimum pipe cover by gravel should be 50 mm, to avoid ingress of the sand transition layer into the pipe. Where the submerged zone material is gravel-based, this also serves as the drainage layer (Figure 4, bottom).

☝ DESIGN TIP

- Shaping the of bottom of system: if a design objective is to collect as much water as possible, the bottom of the system should be shaped to define a flow path towards the underdrain (left). However, if the goal is to exfiltrate water to the surrounding soil, then the bottom of system should be flat (centre), particularly if the pipe is raised above the bottom of the system (right, see Section 3.5.10 for further details on this latter configuration).



IMPORTANT!

- Geotextile fabrics are a clogging risk and are ***not*** recommended anywhere within the filter profile i.e., to separate layers, or around drainage pipes. An open-weave shade cloth can be placed between the filter media and the drainage layer to help prevent the downward migration of smaller particles if required, however this is only recommended where there is insufficient depth for a transition layer. A geotextile can be used to line the walls, but this is not considered necessary in most cases.

3.5.10 Underdrain

For lined standard biofiltration systems:
Slotted PVC pipes are preferable to flexible perforated ag-pipe, as they are easier to clean and ribbed pipes are likely to retain moisture which may attract plant roots into pipes. The upstream end of the collection pipe should extend to the surface to allow inspection and maintenance; the vertical section of the pipe should be unperforated and capped (Figure 16). Where more than one collection pipe is required, these should be spaced no further than 1.5 m apart.

The following need to be checked:

a) Perforations in pipe are adequate to pass the maximum infiltration rate.

b) Pipe has sufficient capacity to convey the treated water; this component should be oversized to ensure that it does not become a choke in the system.

c) Material in the drainage layer will not wash into the perforated pipes.

For unlined standard biofiltration systems with underdrain:
In order to promote exfiltration, the collection pipe can be raised from the bottom of the drainage layer. In this case, the depth of the drainage layer = 50 mm pipe cover + pipe diameter + depth from invert of pipe to bottom of drainage layer (Figure 18). However, the collection pipe must still be sized to convey the maximum infiltration rate in the same way as for lined standard biofiltration systems, to ensure that the system will be operational even without exfiltration (i.e., in case the bottom of the system clogs).

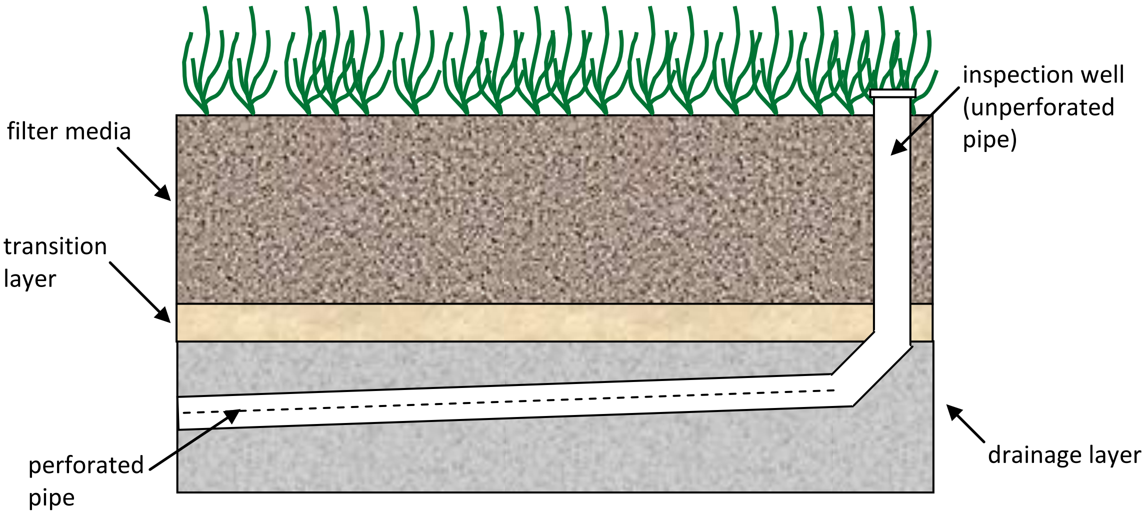


Figure 18. Long section of a biofiltration system showing collection pipe raise above bottom of drainage layer to promote exfiltration. Note series of 45° elbows rather than 90° elbows, to facilitate entry of maintenance equipment (eg. pipe snake or water jet).

For biofiltration systems containing a submerged zone:

There are two possible configurations for an underdrain in a biofiltration system with a submerged zone:

1. Perforated collection pipe with riser outlet

In this configuration, the collection pipe(s) is placed in the drainage layer with an elbow to create a riser outlet to raise the invert (Figure 19). The collection pipe(s) does not need to be sloped as the outlet is elevated. Slotted PVC pipes are preferable to flexible perforated ag-pipe, as they are easier to clean and ribbed pipes are likely to retain moisture which may attract plant roots into pipes, however this necessitates a drainage layer to ensure that finer material from the filter media and transition layers are not washed into the collection pipe(s). The upstream end of the collection pipe should extend to the surface to allow inspection and maintenance; the vertical section(s) of the pipe should be unperforated and capped. Where more than one collection pipe is required, these should be spaced no further than 1.5 m apart.

The following need to be checked:

a) Perforations in pipe are adequate to pass the maximum infiltration rate.

b) Pipe has sufficient capacity to convey the treated water; this component should be oversized to ensure it does not become a choke in the system.

c) Material in the drainage layer will not wash into the perforated pipes.

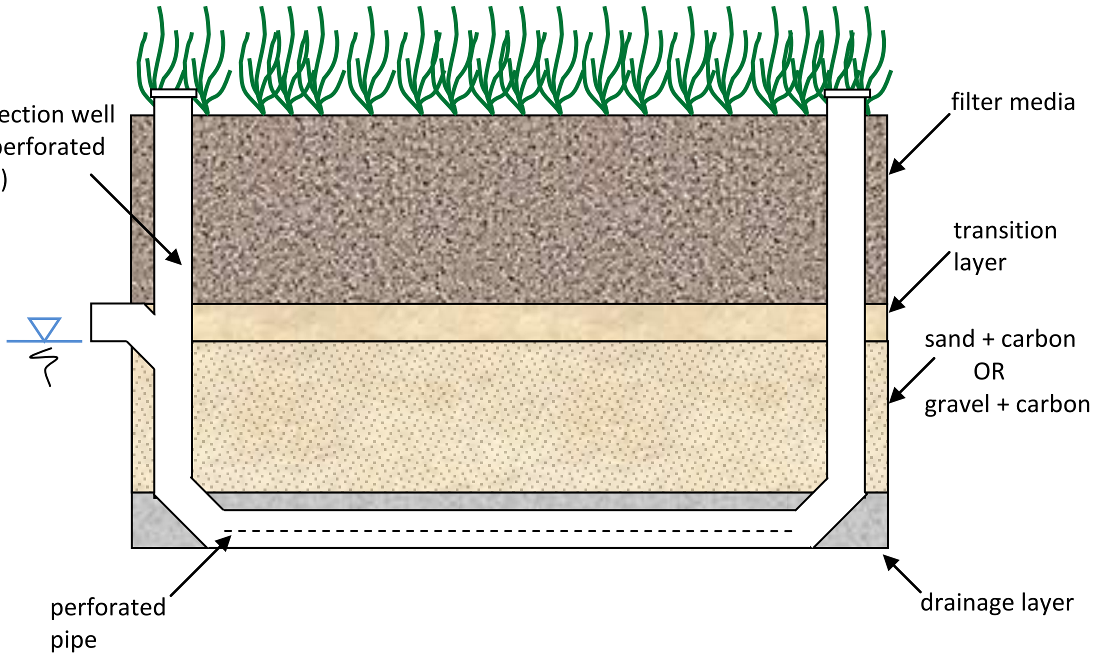


Figure 19. Long section of a biofiltration system with a submerged zone showing collection pipe and riser outlet (Note that, in this system, the transition layer is between the filter media and submerged zone). Note series of 45° elbows rather than 90° elbows, to facilitate entry of maintenance equipment (eg. pipe snake or water jet).

2. Riser outlet only (no perforated pipe)

A collection pipe is not strictly necessary in a biofiltration system with a submerged zone; inclusion of a riser outlet confines exit flow to be via this path and the drainage layer can act as a surrogate collection pipe (Figure 20). The riser outlet should extend to the surface to allow inspection and maintenance.

The following need to be checked:

a) Pipe has sufficient capacity to convey the treated water; this component should be oversized to ensure it does not become a choke in the system.

b) Material in the drainage layer will not wash into the riser outlet.

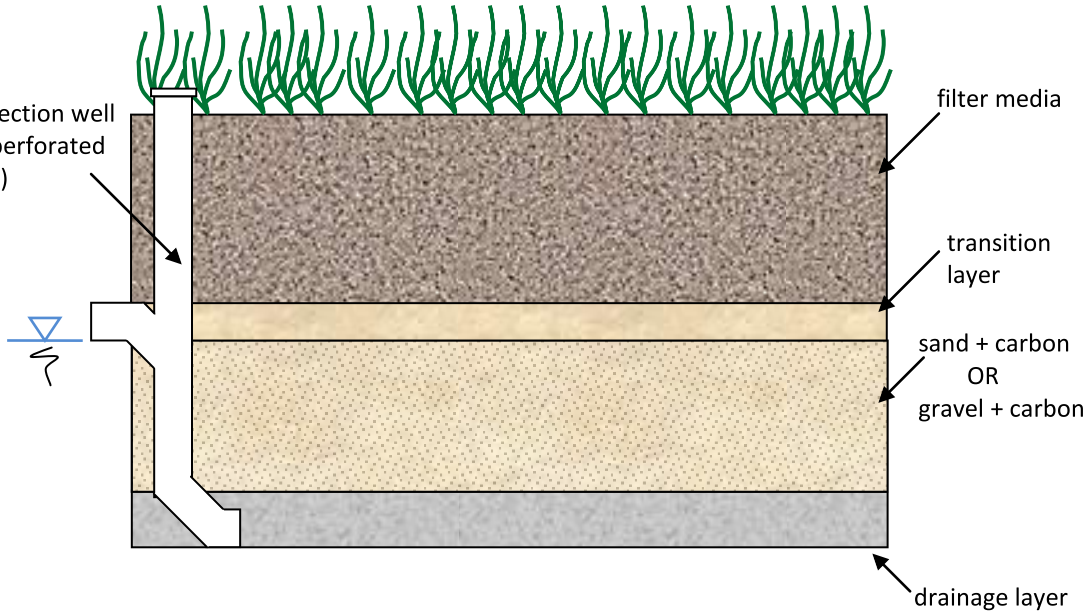


Figure 20. Long section of a biofiltration system with a submerged zone showing riser outlet (Note that, in this system, the transition layer is between the filter media and submerged zone). An appropriate screen should be placed over the outlet pipe entry in the drainage layer, to prevent ingress of gravel.

DESIGN TIP

- The perforations in the collection pipes should be small enough that the drainage layer cannot fall into the pipes. A useful guide is to check to that the D_{85} (drainage layer) is greater than the pipe perforation diameter.
- Use 45^o connectors to soften the bends in the collection pipe(s) for easier maintenance access.
- Place screen over entry into outlet pipe in gravel drainage layer, to avoid ingress of gravel into pipe.

3.5.11 Liner

The following are feasible options for lining a biofiltration system, where an impermeable liner is necessary:

1. Compacted clay

Where the hydraulic conductivity of the surrounding soil is naturally very low (i.e., the saturated hydraulic conductivity of native soil is 1 – 2 orders of magnitude less than that of the filter media) flow will preferentially be vertical to the underdrain and little exfiltration will occur. Here, it may be deemed sufficient to compact the sides and bottoms of the system.

2. Flexible membrane

A heavy duty flexible membrane, such as high-density polyethylene (HDPE), can be used to line the base and sides of the drainage layer. It is unlikely that sides higher than this will need to be lined, as flow will preferentially be vertical and there is little opportunity for exfiltration through sides of the system.

IMPORTANT!

- For an unlined biofiltration system with a submerged zone, the bottom and sides of the submerged zone still need to be lined in order to maintain a permanent pool of water.

DESIGN TIP

- Where an impermeable liner is not required, geotextile can be used to line the walls and delineate the system from the surrounding soils, however this is optional.

3.5.12 Vegetation

1. Specify vegetation type

Plants are essential for ensuring effective removal of nutrients, particularly nitrogen, as well as for maintaining the long-term infiltration capacity of biofiltration systems. However, some species are more effective than others in their ability to adapt to the conditions within a biofilter, along with their influence on the nutrient removal and hydraulic conductivity of the biofilter.

a) Prepare potential species list

A list of potentially suitable species should be drafted; desirable plant traits for nutrient removal are listed in Table 3. Other useful sources of information include local plant experts, local council, nurseries, and reference books. Potentially suitable species may be native or introduced; this will determined by biodiversity considerations, site conditions, design objectives (eg. treatment, habitat creation), and the surrounding landscape (eg. aesthetic considerations, shade). It is important to note that the example plants listed in **Table 3** are not meant to be exhaustive or exclusive. Other plants which share the same desirable traits are likely to be appropriate. However, we recommend wherever possible that at least 50% of the plants be made up of Type A plants, that is, plant species that have been shown to be effective for nutrient removal (**Table 3**). Where possible, these should be evenly spread across the biofilter surface, to ensure optimum performance.

In terms of maintaining infiltration capacity, results from field-scale testing suggests that any plant species will be useful. However, if this issue is of particular concern, it is recommended that plant species with thick roots, such as *Melaleuca ericifolia*, be specified.

Table 3. Desirable plant traits for biofiltration systems and example plants (Bratieres *et al.*, 2008; Read *et al.*, in press).

Objective	Desirable traits	Example plants	
		Type A*	Type B*
Nutrient removal	• High relative growth rate • High total root, leaf & shoot biomass • High root density • High root: shoot ratio • High length of longest root • High leaf area ratio	• *Carex appressa* • *Melaleuca ericifolia* • *Goodenia ovata* • *Ficinia nodosa* • *Juncus amabilis* • *Juncus flavidus*	• *Microlaena stipoides* • *Dianella revoluta* • *Leucophyta brownii* • *Lomandra longifolia* • *Banksia marginata* • *Pomaderris paniculosa*

*Type A plants have been demonstrated to be effective for removal of nutrients, while Type B plants have been shown to be non-effective for nutrient removal.

DESIGN TIP

- Use Type A plants wherever possible to ensure effective nutrient removal (see **Table 3** for further details).
- If maintaining a high infiltration capacity is of particular importance, specify inclusion of *Melaleuca ericifolia*.

Where there is a desire to use a plant species other than Type A plants (**Table 3**), or if it is known that Type A plants listed will not grow well in the local climate, the information in Figure 21 can be used to screen potentially useful plant species and compare their expected performance against the tested range. These graphs illustrate the relationship between a number of key plant root traits and total nitrogen phosphorus concentrations in biofilter effluent. Selection of plant species using this approach should be conducted in consultation with a local plant expert. It is suggested that the percent root mass is the most useful trait, as it is the characteristic for which there is already information available or is most easily acquired. For the purposes of direct comparison, it is noted that the plant characteristics illustrated below are for plants that were approximately eleven months old.

b) Assess hydrologic requirements
Suitable species for biofiltration systems need to be tolerant of drought, freely draining filter media and variable periods of inundation.

c) Growth form
Suitable species should have extensive root structures and should not be shallow rooted. Ideally the roots should penetrate the entire filter depth. Dense linear foliage with a spreading growth form is desirable, while clumping structures such as bulbs or large corms should generally be avoided (because they can promote preferential flows around the clumps, leading to erosion).

d) Other
Depending on the site conditions, other possible issues that might need to be considered include frost tolerance, shade tolerance, and landscape requirements (eg. height restrictions). Non-invasive species should always be specified.

e) Hydraulic conductivity of filter media
If a filter medium with a high hydraulic conductivity is specified, specialised plant species are likely to be required (i.e., very drought tolerant), unless a submerged zone is included.

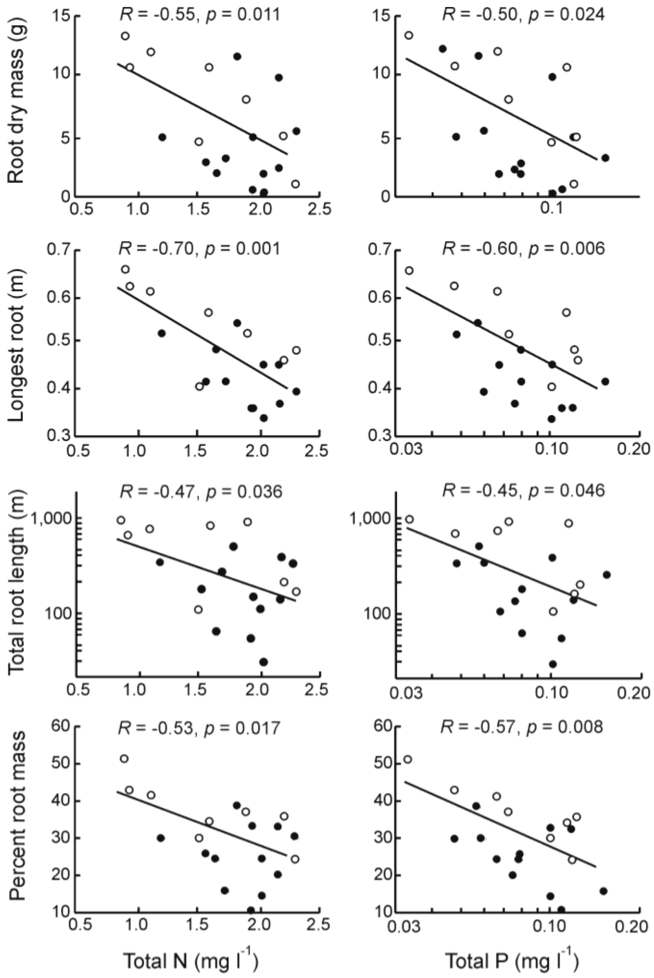


Figure 21. Correlations of plant root traits with total nitrogen and phosphorus concentrations in biofilter effluent. The results of Pearson correlation are given. Note: some axes are $\log_{10}$-transformed. Monocots, open symbols; dicots, filled symbols (after Read *et al.*, in press).

> **SUSTAINABILITY TIP**
>
> - Consider biodiversity and habitat creation when specifying vegetation. In this instance, at least 50% of plants should made up of Type A species (see **Table 3**), while the remainder should be specified according to the design objective.

2. Other design considerations

- Planting density

The overall planting density should be high (at least 10 plants/m^2 for sedges and rushes) to increase root density, protect surface porosity, promote even distribution of flows, increase evapotranspiration losses (which helps to reduce runoff volume and frequency), and reduce the potential for weed invasion. One exception to this recommendation may be the case where the biofilter is providing pre-treatment for a stormwater harvesting system. In that case, it may be desirable to reduce evapotranspiration by minimising plant densities. However, caution should be applied in this case, because very low densities will increase the likelihood of weed invasion.

- Zoning in large systems

In large biofiltration systems, areas furthest from the inlet may not be inundated during small rain events. Plants in these areas may therefore need to be particularly hardy and tolerant of drying conditions. Conversely, plants near the inlet may be frequently inundated, and potentially impacted by higher flow velocities, and so plants capable of tolerating these conditions should be selected.

- Range of species

Vegetating a biofilter with a range of species increases the robustness of the system, because it allows species to “self-select” i.e., drought tolerant plants will dominate in areas furthest from the inlet, while plants that prefer wetter conditions are likely to thrive nearer the inlet.

- Layout of planting

Dominant species should be planted extensively; at a density of 8 – 12 plants/m^2, depending on the growth form. Shrubs and trees should be planted at density of <1 plant/m^2 and according to landscape requirements. Batters should be planted with species that are tolerant of drier conditions.

- Mulch

The use of an organic mulch should generally be avoided for systems where there is an overflow pit, due to the risk of clogging. In the case of bio-infiltration, a mulch may be used, however there is still a risk of excessive movement of material during high flows. A gravel mulch may be used where there is a need to protect the soil from erosion or decrease the drop to the ponding zone (for safety reasons), whilst still maintaining an acceptable ponding volume (see Section 3.6.1). However, high planting densities should be used, to compensate for the reduced spread of plants caused by the gravel mulch.

3. Timing for planting

In temperate climates, planting should be undertaken generally late in winter or early in spring, to allow sufficient time for the plants to get established before the hot summer period. In tropical or sub-tropical climates, appropriate planting times will vary, and generally be at the beginning of the wet season. Local botanists or nurseries should be consulted.

3.6 OTHER CONSIDERATIONS

3.6.1 General

Edge treatments: are required to keep traffic (vehicular and pedestrian) away from the filter surface to avoid reduced infiltration capacity due to compaction as well as damage to the structural components (inlet, outlet, etc.); the consequence of reduced infiltration capacity would likely be more frequent overflows. This will also serve to ensure public safety as well as to define clear lines for maintenance boundaries.

- For pedestrian traffic: dense planting, fencing, etc. may be used.

- For vehicular traffic: where there is the likelihood of vehicles mounting the kerb (eg. on a bend), concrete edge restraints should be used, although these may not be required on traffic buildouts where landscaping is behind the kerb.

Pre-treatment (clogging prevention): the need for this will be determined by the size of the bioifltration system and the expected sediment load i.e., systems that are small relative to the size of their catchment or where sediment concentrations are high should include some sort of pre-treatment measure (eg., sedimentation pond, buffer strip, sedimentation pit/tank, sediment forebays) to protect against premature failure due to clogging. Care should be taken to identify any potential sources of high pollutant loads (eg. non-vegetated or damaged existing treatment systems, unsecured batters, high numbers of deciduous tress). In the case of biofiltration swales, the swale component is likely to provide sufficient pre-treatment to protect the biofiltration component.

Other:

- Safety – eg. maintaining clear sightlines for traffic and pedestrians
- Consider owners of other infrastructure – will maintenance of these assets impact on the biofiltration system? Will installation of a biofiltration system adjacent to other infrastructure impact access to these assets? (see Section 3.6.2 for further discussion)
- In some cases, local planning and development guidelines conflict with WSUD (eg. kerb type) – as discussed in Chapter 2 (*Planning for Biofiltration*) these documents are likely to be reviewed as WSUD becomes more mainstream, however, in the meantime, conflicts might need to be resolved on a case-by-case basis.
- Effective use of available space - breaking up the catchment

IMPORTANT!

- Steep slopes can be difficult due to high flow velocities, which can lead to scour and erosion problems. Where slopes are steep, it is critical that inflows are tightly controlled. Additionally, the use of linear systems that incorporate check dams to restrict flow velocities may be more useful than basins. Where slopes exceed 5%, biofiltration swales are unlikely to be a feasible stormwater management option.
- It is ***strongly recommended*** that biofilters are vegetated, as plants have been demonstrated to play a key role in preventing nutrient leaching and maintaining infiltration capacity. Further, it is unlikely that non-vegetated soil-based filters will remain so; rather, they will be populated by weeds.
- For larger bioretention systems, a maintenance access track for maintenance vehicles (eg. 4WD ute) should be provided to the full perimeter of the system for maintenance efficiency and ease.

3.6.2 Interaction with services

Potential conflicts with other services (eg. gas, sewer, electricity, telecommunications) can be problematic, particularly in retrofit situations. However, the use of creative design can overcome many of these options. For example, there are numerous cases of biofiltration systems successfully built surrounding services. Regardless, the relevant service authorities should be consulted.

DESIGN TIP

Ideas for ensuring both filter integrity and public safety

Seating also serves to keep pedestrian traffic away from filter surface

A broken kerb distributes inflow and keeps vehicles away from the filter surface

A deep gravel layer on the filter surface provides extra extended detention whilst still ensuring pedestrian safety by avoiding large steps, although this design solution is likely to restrict the spread of vegetation.

Use of a bio-infiltration system can provide additional flexibility in dealing with intersecting services, because they do not require an underdrain. For example, where a sewer line intersects the proposed site, a bio-infiltration system could be constructed in two parts – one each side of the sewer line, with a connecting pipe in between them (Figure 22).

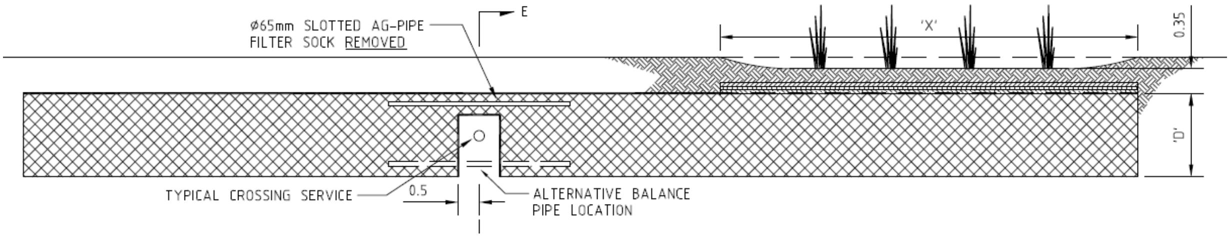


Figure 22. Example of innovative design to overcome interaction with services. In this example, the bio-infiltration system is constructed either side of a sewer line, with a connecting pipe in between, avoiding excavation underneath and surrounding the sewer.

3.6.3 Biofiltration Swales

- Check dams (located at regular intervals along the swale) will be required in steeper areas to control flow velocities and to maximise the opportunity for infiltration to occur.
- In flat areas, it is important to ensure adequate drainage to avoid prolonged ponding.
- Where biofiltration swales are installed in median strips, provision for pedestrian crossings must be incorporated.
- Where biofiltration systems are installed in nature strips, driveway crossings must be incorporated, and consideration to interaction with other services must be given, at the start of the design process.

3.6.4 Stormwater Harvesting

- Given their effective treatment of pollutants, biofilters are certainly a suitable treatment option for stormwater harvesting with respect to water quality. However, biofilters also reduce runoff volumes by an average of 30% due to evapotranspiration, thus reducing available yield.
- In order to maximise the volume of treated water, a lower planting density could be used, but this is likely to reduce the treatment capacity (for nutrients only). However, for most stormwater harvesting applications (eg. irrigation, toilet flushing), nutrient removal is not critical, therefore it is worth considering using a lined system that is vegetated with small plants such as grass to minimise evapotranspiration losses (suspended solids and heavy metals will still be effectively removed).
- For stormwater harvesting applications where treatment of pathogens is critical, biofilters can provide effective pre-treatment – while they do not reduce pathogen concentrations to levels that satisfy water quality criteria, they improve the quality of the stormwater such that post-disinfection (eg. UV disinfection) will be effective.

DESIGN TIP

- Where nutrient removal is not critical, use a lined system and small plants such as grass to maximise the yield of treated stormwater. Avoid the use of trees and other large, "water hungry" plant species.
- Where pathogen removal is essential, include post-disinfection such as UV treatment.

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